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United States Patent [19]

Chen et al.

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[54] **SYSTEM AND METHOD FOR SENSING THE DRYNESS OF CLOTHING ARTICLES**

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[73] Assignee: **General Electric Company**, Schenectady, N.Y.

[*] Notice: This patent is subject to a terminal disclaimer.

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[22] Filed: **Mar. 13, 1997**

[51] **Int. Cl.**[7] **F26B 21/06**

[52] **U.S. Cl.** **34/475**; 34/491; 34/495; 34/557; 34/565

[58] **Field of Search** 34/491, 474, 475, 34/495, 496, 497, 535, 557, 549, 565; 340/660; 318/798, 799, 805, 806; 219/490, 494, 497

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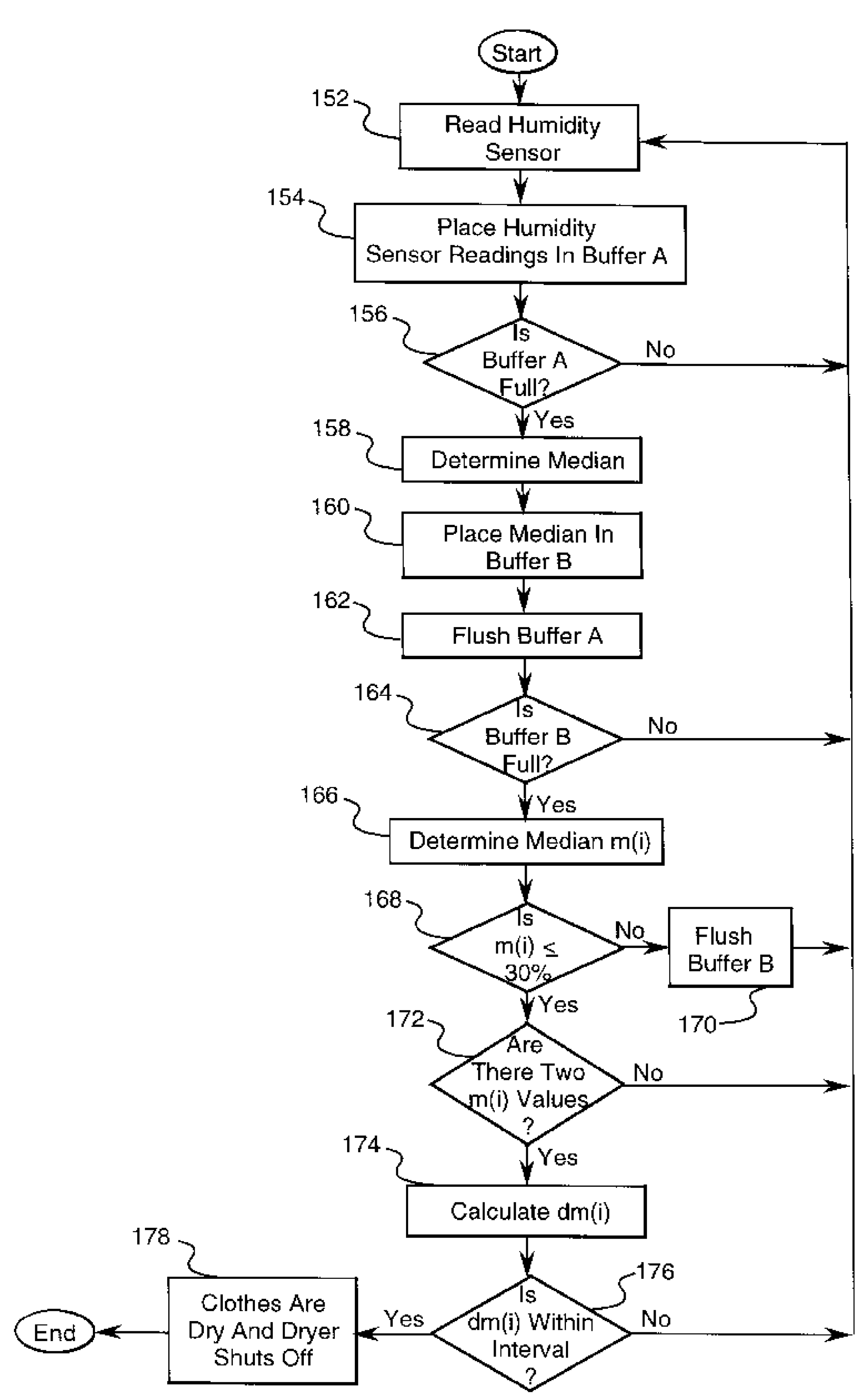
U.S. Patent Application "System and Method for Predicting the Dryness of Clothing Articles" by Y.Chen, et al, Attorney Docket No. RD–25,237, Serial No. 08/816591, filed Mar. 13, 1997.

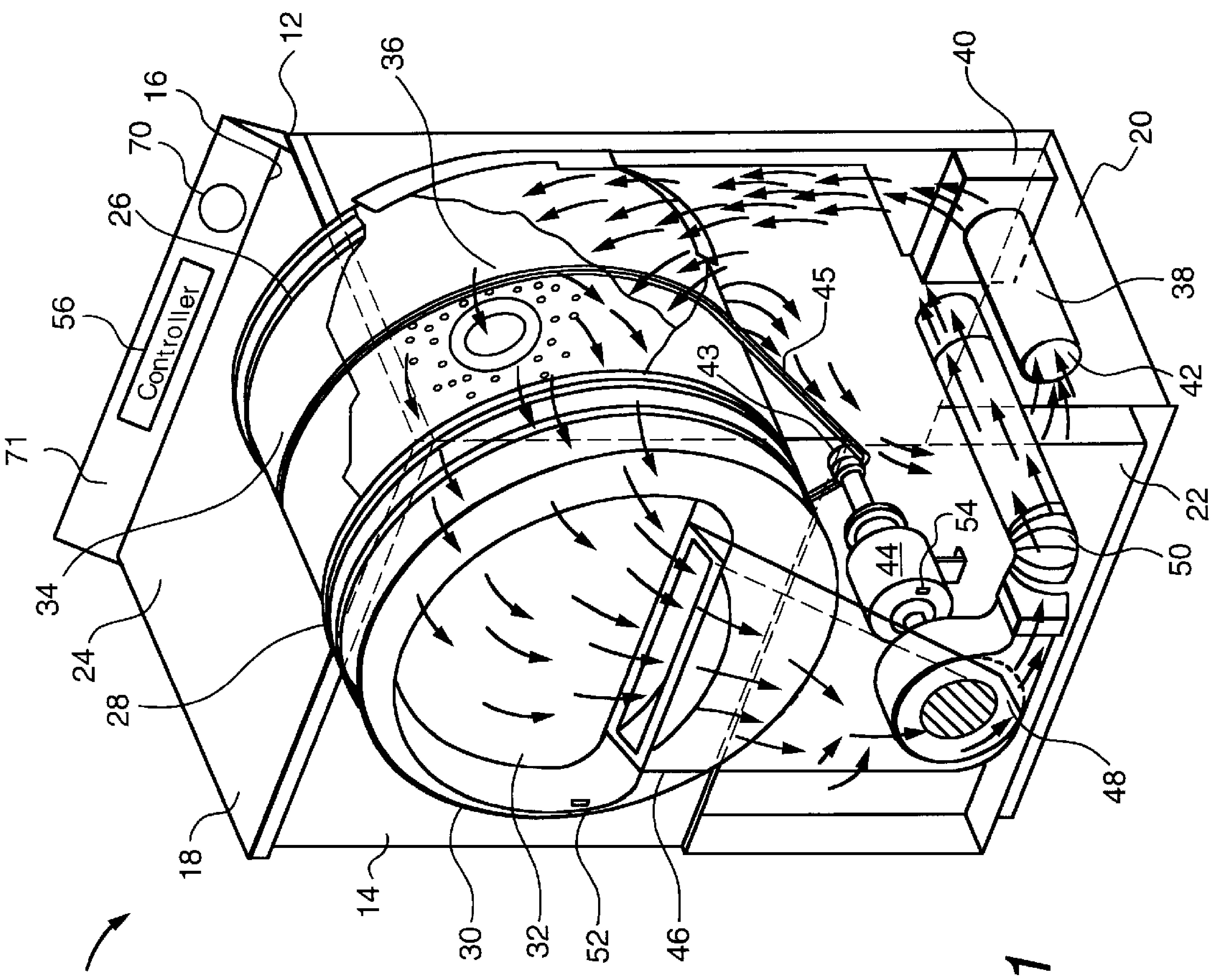
Primary Examiner—Pamela A. Wilson
Attorney, Agent, or Firm—Dave C. Goldman; Jill M. Breedlove

[57] **ABSTRACT**

A system and method for sensing the dryness of clothing articles in a clothes dryer. In one embodiment, the clothes dryer uses a temperature sensor and a phase angle sensor to determine the dryness of the clothing articles as a function of the heated air temperature and the motor phase angle. In another embodiment the clothes dryer uses a humidity sensor to determine the dryness of the clothing articles as a function of the humidity of the heated air temperature. In a third embodiment the clothes dryer uses a temperature sensor, a phase angle sensor, and a humidity sensor to determine the dryness of the clothing articles as a function of the heated air temperature, the motor phase angle, and the humidity of the heated air temperature.

59 Claims, 12 Drawing Sheets

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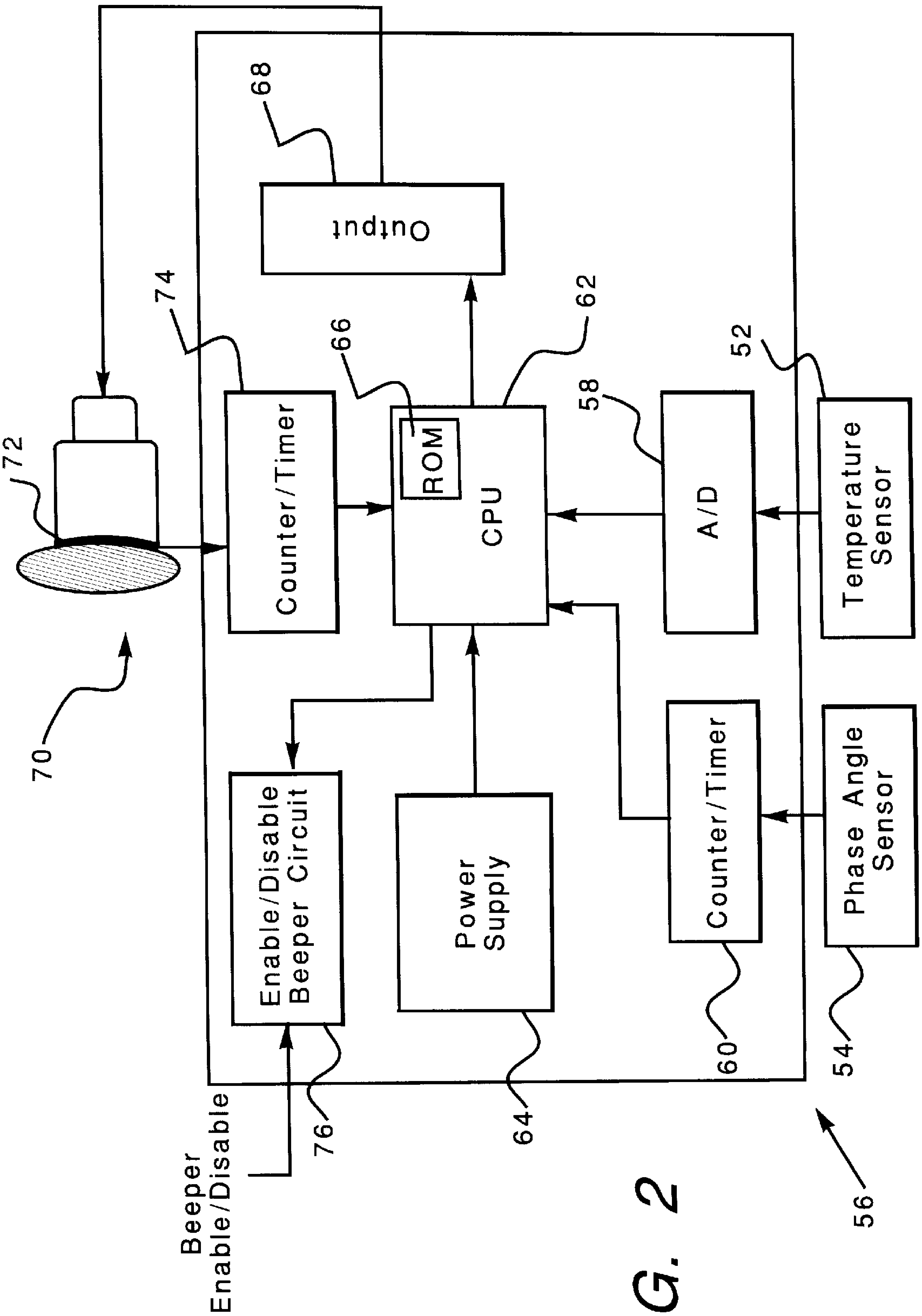
52
54
56
70
71
Controller

FIG. 1



68
Output
74
66
62
72
Counter/Timer
ROM
CPU
58
52
A/D
Temperature Sensor
70
Enable/Disable Beeper Circuit
Power Supply
Counter/Timer
Phase Angle Sensor
60
54
76
64
Beeper Enable/Disable
56

FIG. 2

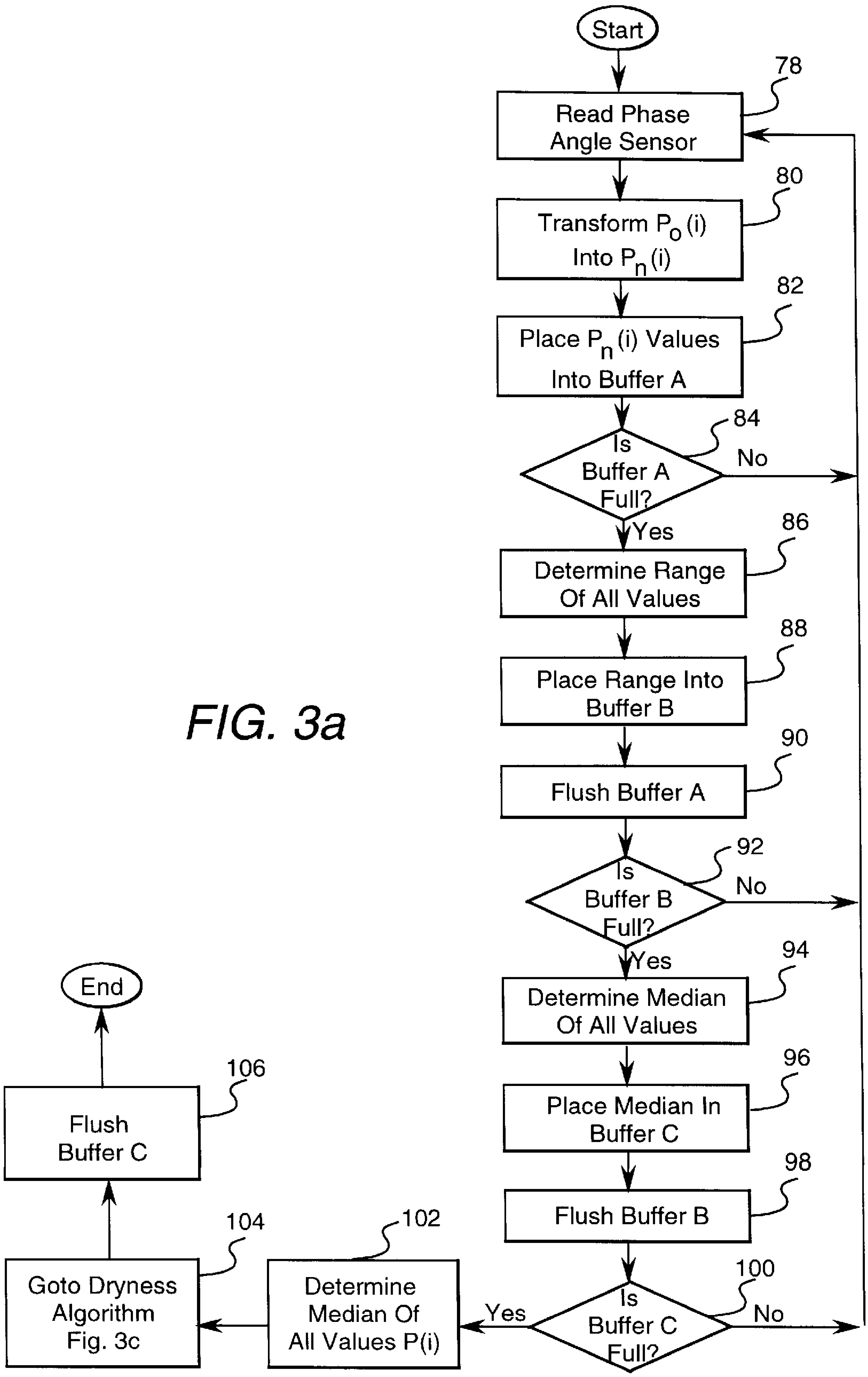

Start
Read Phase Angle Sensor
78
Transform P_o (i) Into P_n (i)
80
Place P_n (i) Values Into Buffer A
82
Is Buffer A Full?
84
No
Yes
Determine Range Of All Values
86
Place Range Into Buffer B
88
Flush Buffer A
90
Is Buffer B Full?
92
No
Yes
Determine Median Of All Values
94
Place Median In Buffer C
96
Flush Buffer B
98
Is Buffer C Full?
100
No
Yes
Determine Median Of All Values P(i)
102
Goto Dryness Algorithm Fig. 3c
104
Flush Buffer C
106
End

FIG. 3a

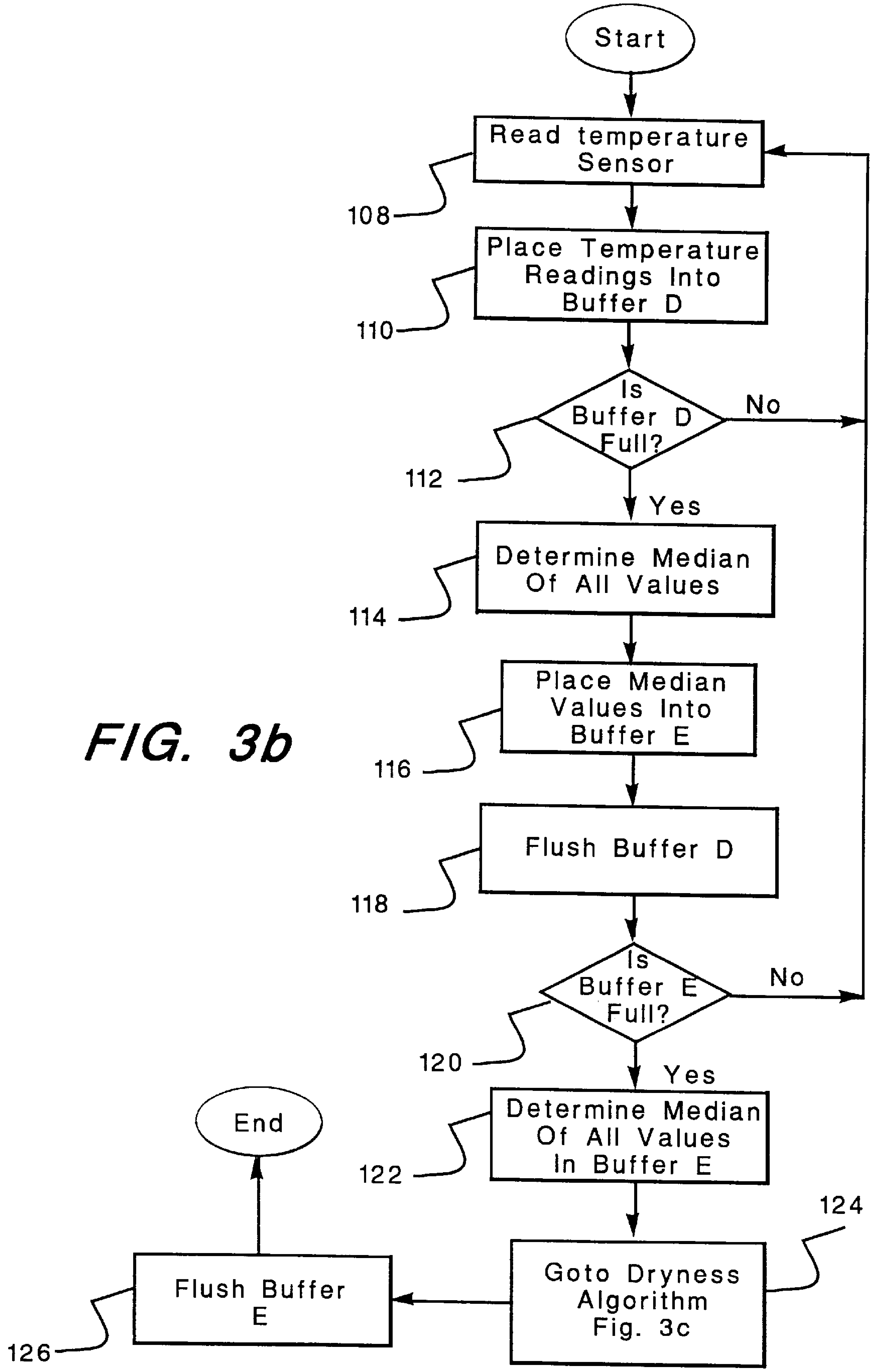

Start
Read temperature Sensor
108
Place Temperature Readings Into Buffer D
110
Is Buffer D Full?
112
No
Yes
Determine Median Of All Values
114
Place Median Values Into Buffer E
116
Flush Buffer D
118
Is Buffer E Full?
120
No
Yes
Determine Median Of All Values In Buffer E
122
Goto Dryness Algorithm Fig. 3c
124
Flush Buffer E
126
End

FIG. 3b

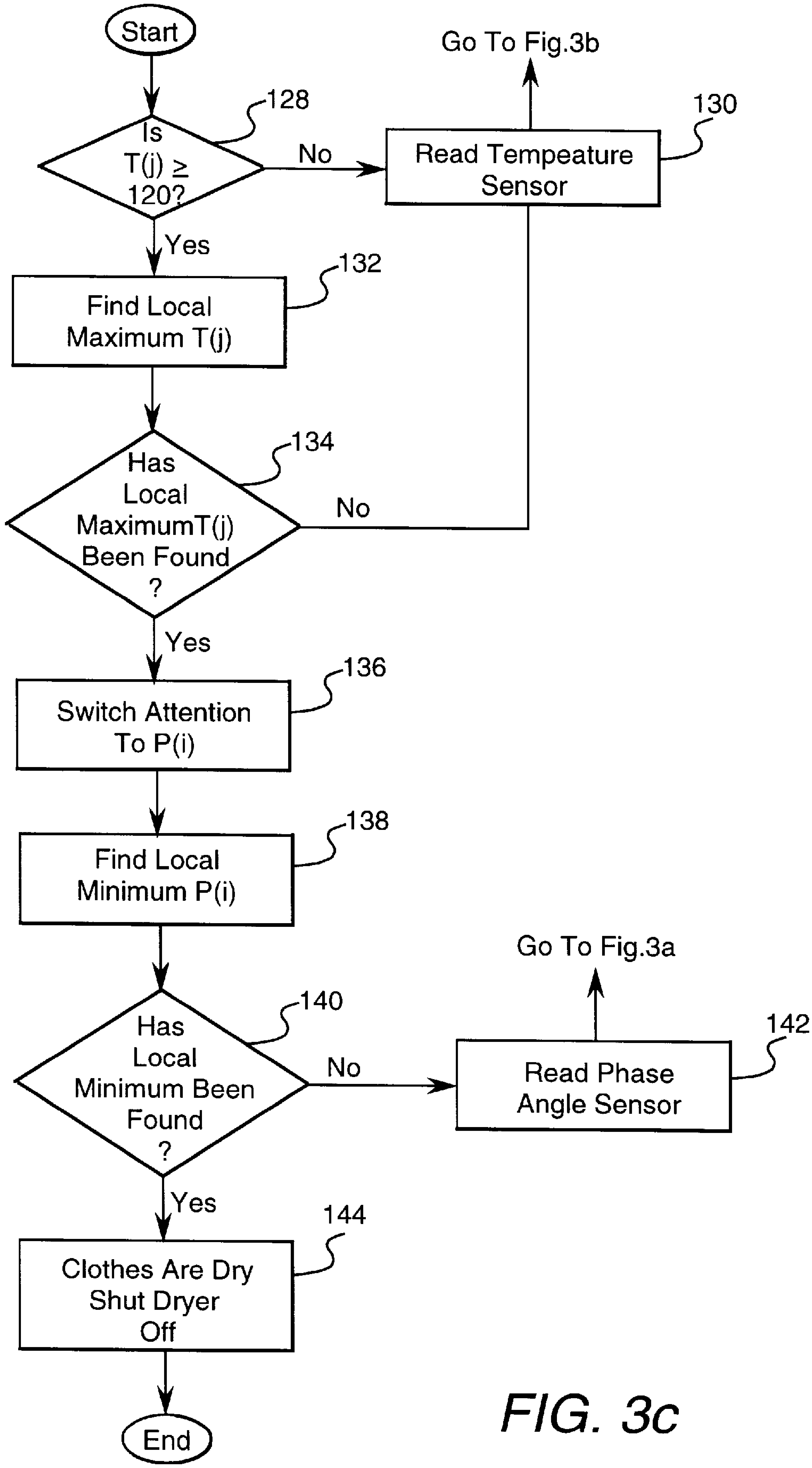

Start
Is T(j) ≥ 120?
128
No
Read Tempeature Sensor
130
Go To Fig.3b
Yes
Find Local Maximum T(j)
132
Has Local MaximumT(j) Been Found ?
134
No
Yes
Switch Attention To P(i)
136
Find Local Minimum P(i)
138
Has Local Minimum Been Found ?
140
No
Read Phase Angle Sensor
142
Go To Fig.3a
Yes
Clothes Are Dry Shut Dryer Off
144
End

FIG. 3c

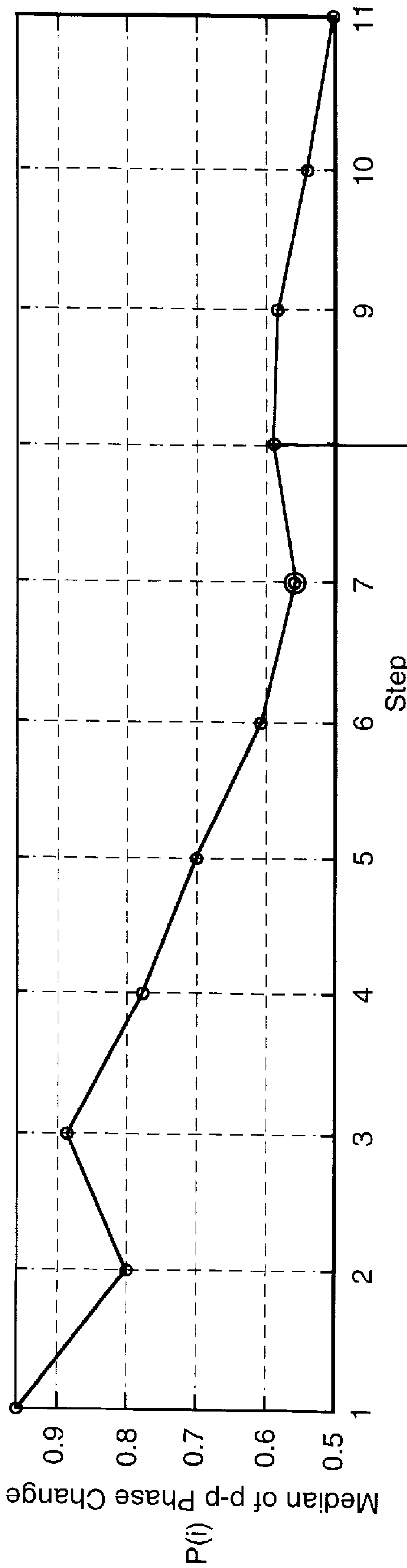


FIG. 4a

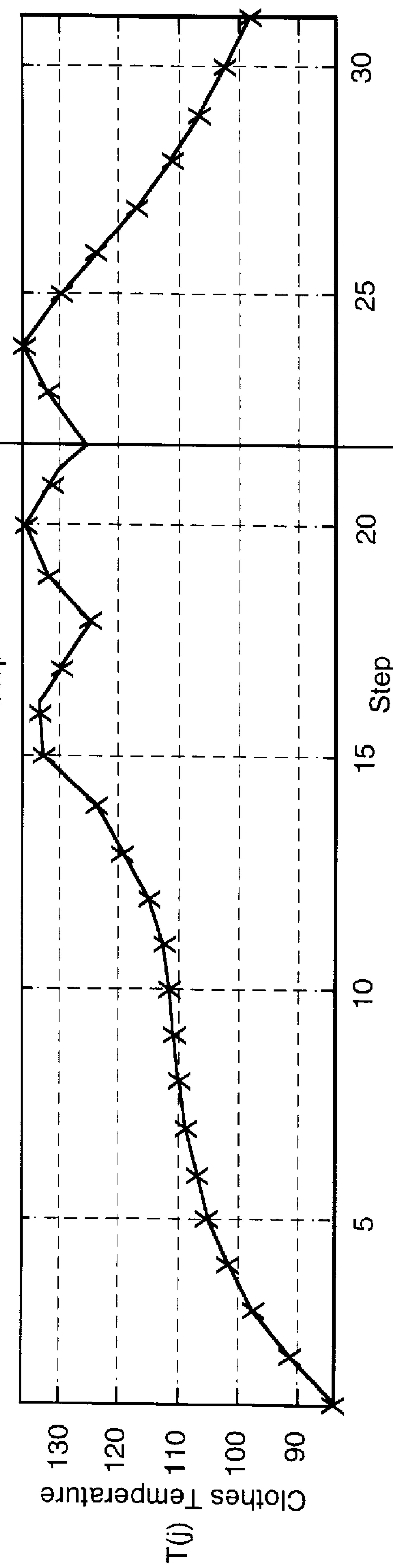


FIG. 4b

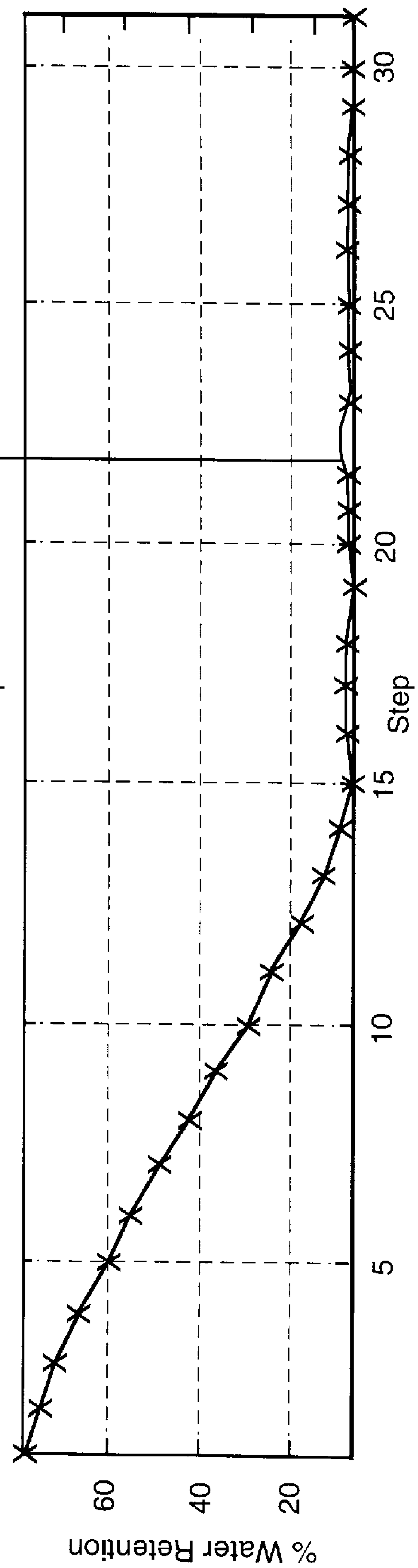


FIG. 4c

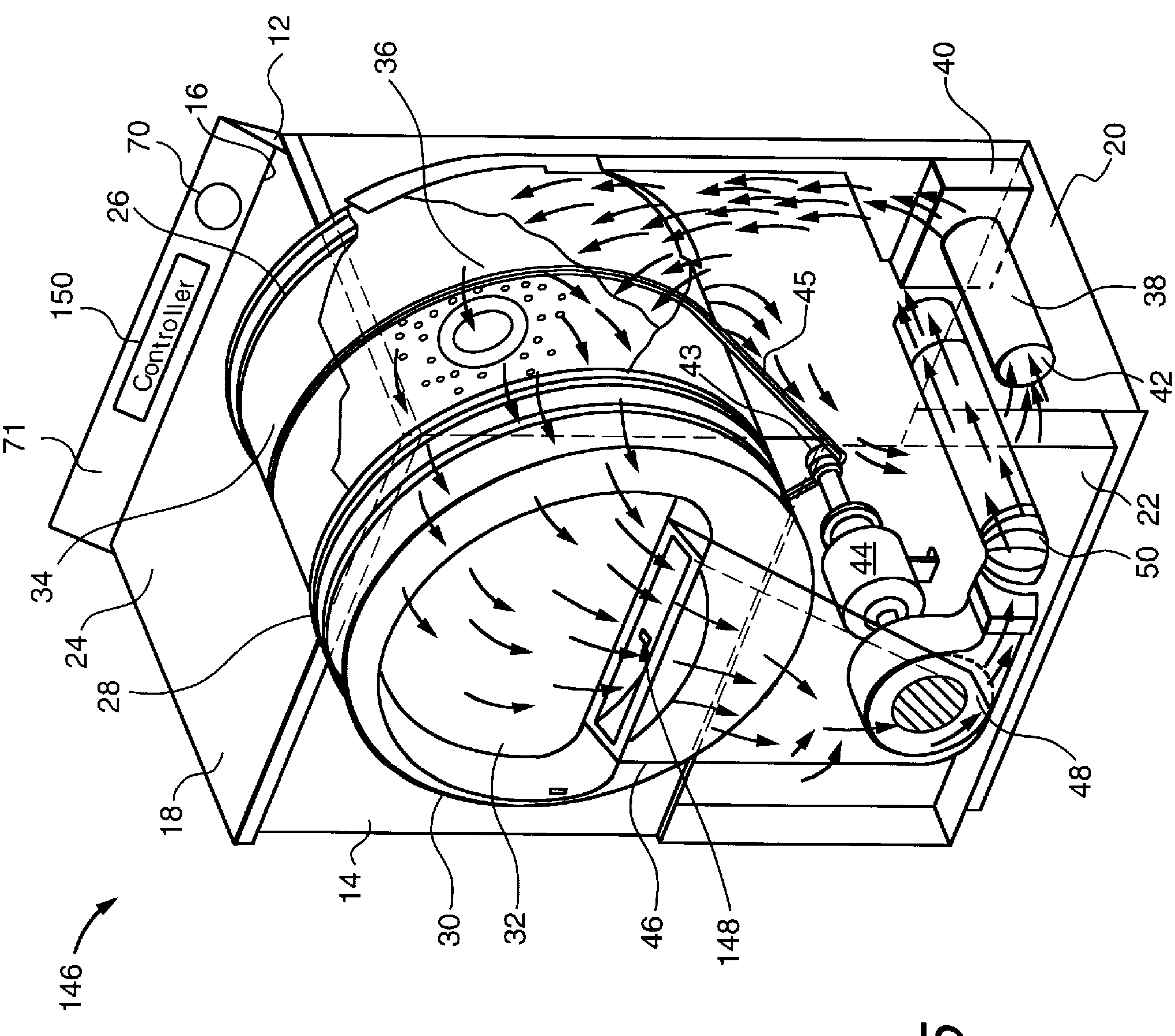
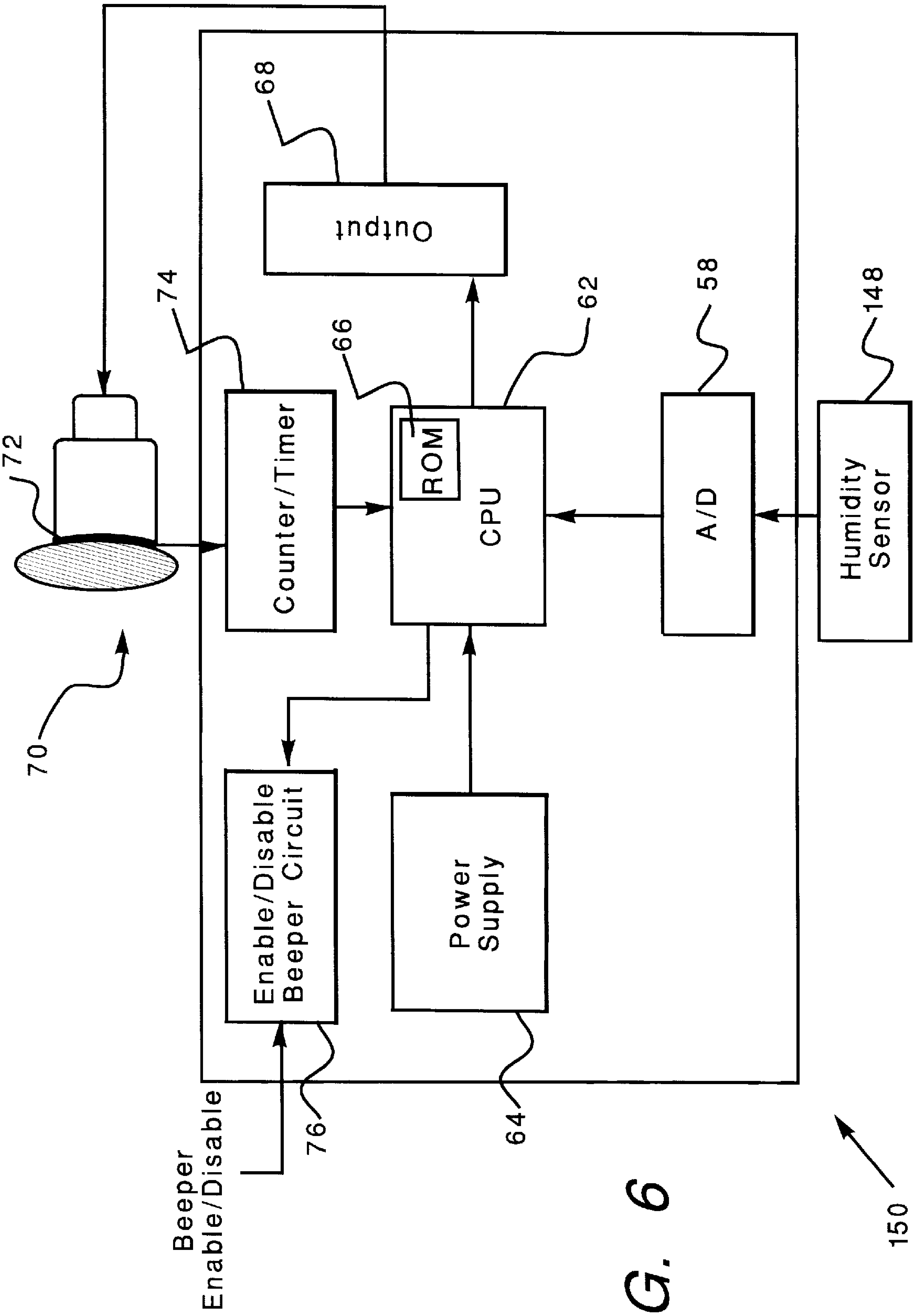

Controller
146
12
16
70
26
150
71
34
24
28
18
14
30
32
46
148
36
40
20
38
42
45
43
44
22
50
48

FIG. 5



Output
68
74
66
62
58
148
72
ROM
Counter/Timer
CPU
A/D
Humidity Sensor
70
Enable/Disable Beeper Circuit
Power Supply
Beeper Enable/Disable
76
64
150

FIG. 6

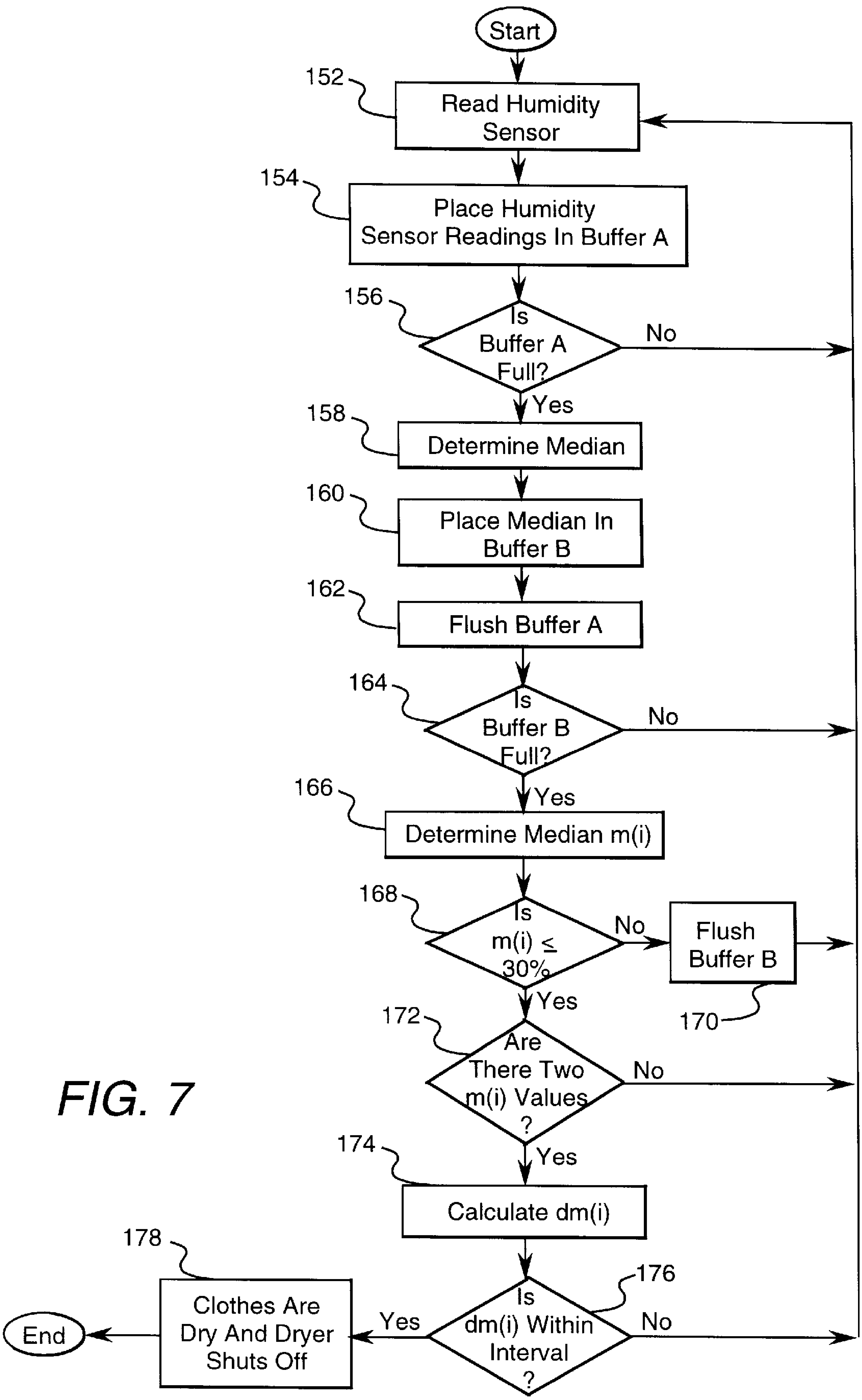

Start
152
Read Humidity Sensor
154
Place Humidity Sensor Readings In Buffer A
156
Is Buffer A Full?
No
Yes
158
Determine Median
160
Place Median In Buffer B
162
Flush Buffer A
164
Is Buffer B Full?
No
Yes
166
Determine Median m(i)
168
Is m(i) ≤ 30%
No
Flush Buffer B
170
Yes
172
Are There Two m(i) Values ?
No
Yes
174
Calculate dm(i)
176
Is dm(i) Within Interval ?
No
Yes
178
Clothes Are Dry And Dryer Shuts Off
End

FIG. 7

FIG. 8a

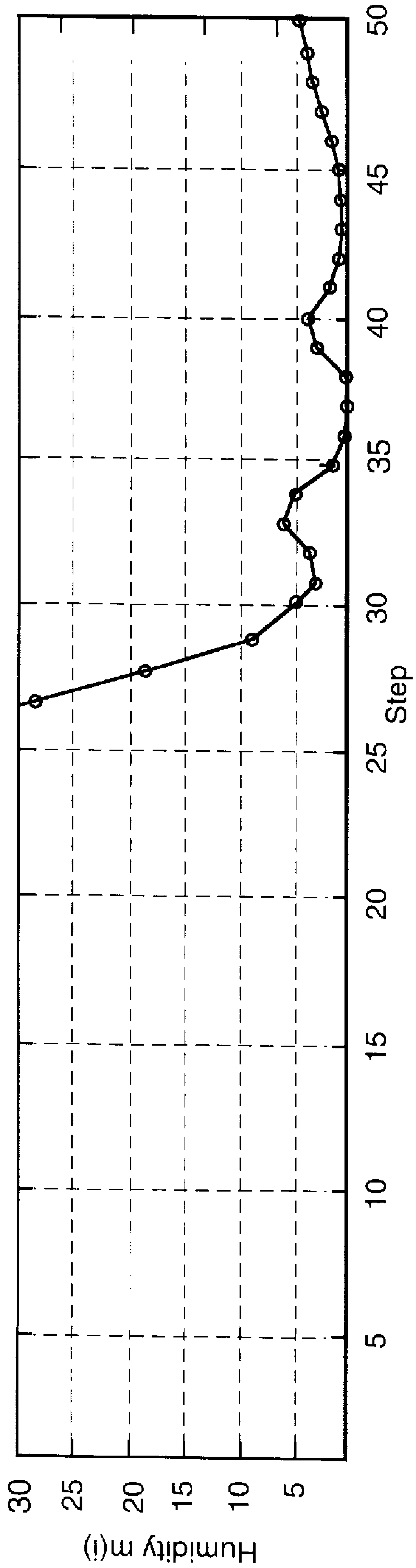


FIG. 8b

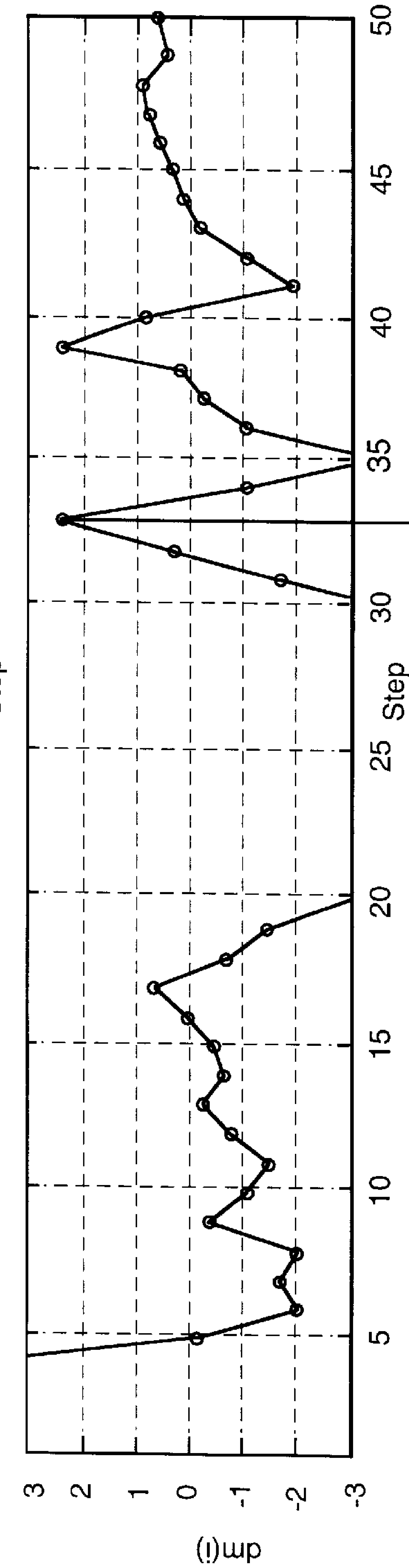
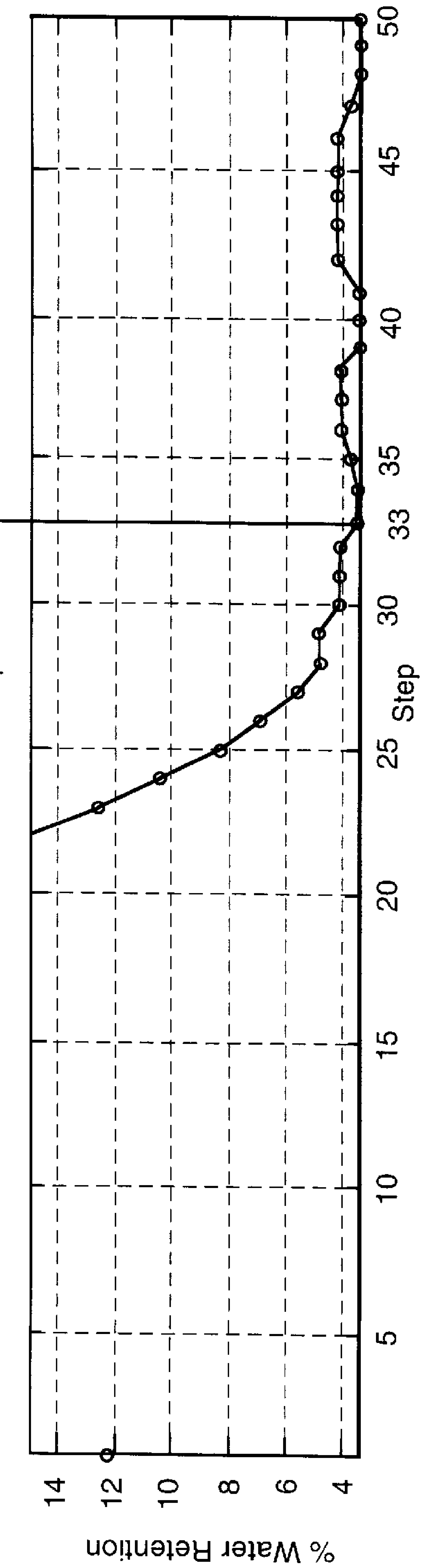


FIG. 8c



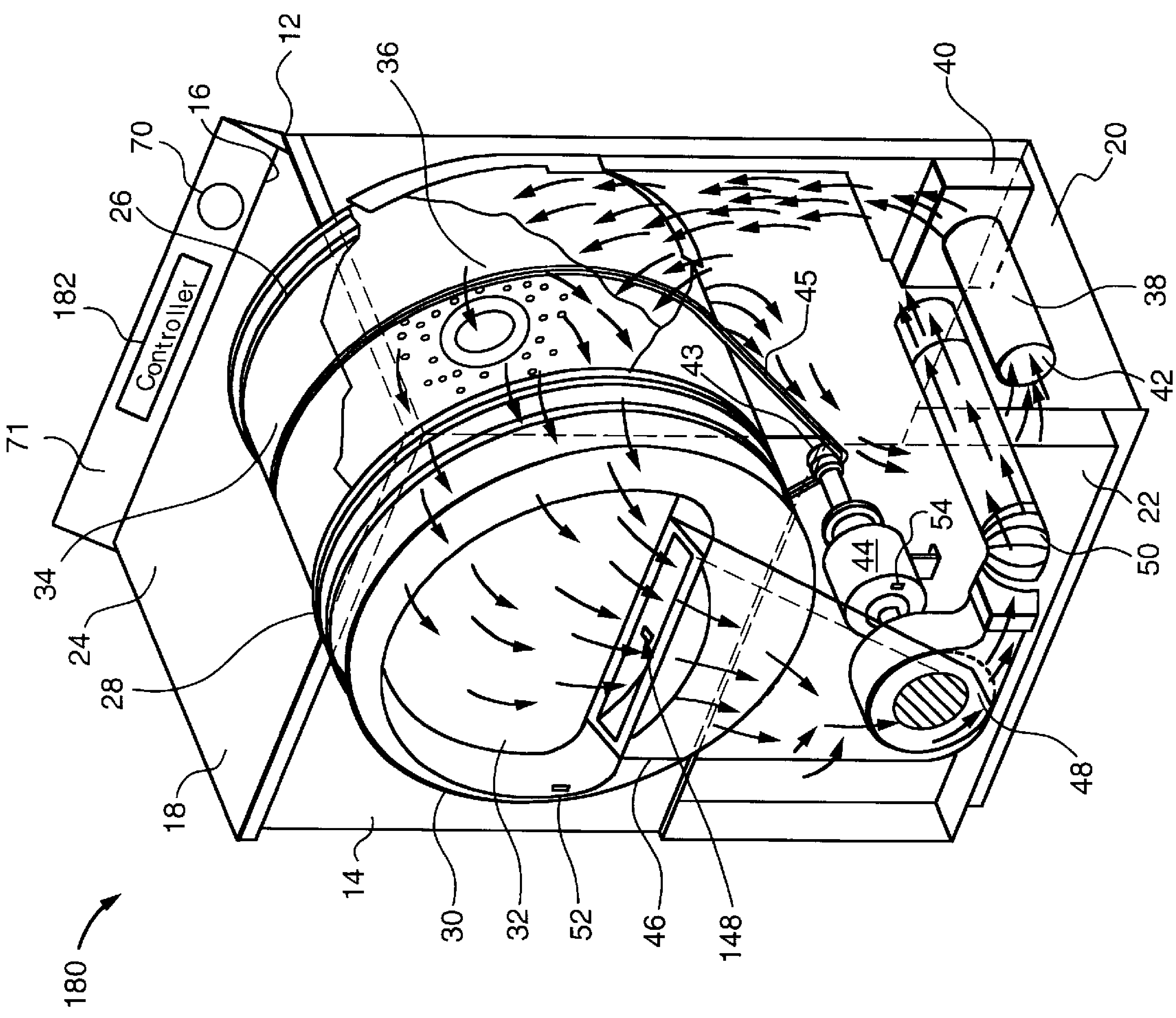
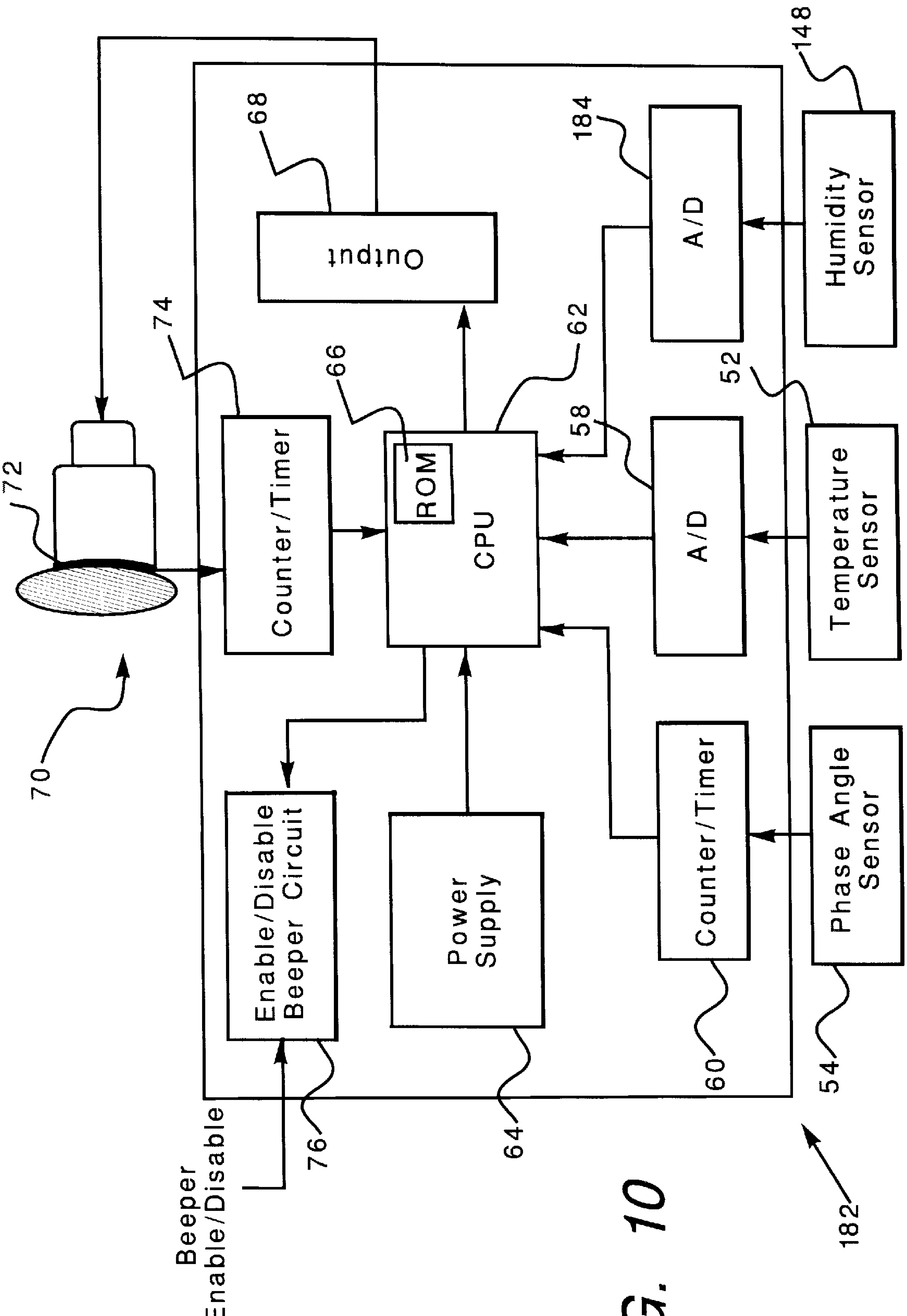

Controller
180
182
71
70
16
12
26
36
40
20
38
42
45
43
34
24
28
18
14
30
32
52
46
148
48
50
22
54
44

FIG. 9



Output
68
74
Counter/Timer
66
ROM
CPU
62
184
A/D
148
Humidity Sensor
52
58
A/D
Temperature Sensor
72
70
Enable/Disable Beeper Circuit
Power Supply
Counter/Timer
Phase Angle Sensor
76
64
60
54
Beeper Enable/Disable
182

FIG. 10

SYSTEM AND METHOD FOR SENSING THE DRYNESS OF CLOTHING ARTICLES

FIELD OF THE INVENTION

The present invention relates generally to an appliance for drying articles, and more particularly to a system and method for sensing the dryness of the articles in the appliance.

BACKGROUND OF THE INVENTION

Typically, an appliance for drying articles such as a clothes dryer for drying clothing articles uses an open control loop to dry the articles. The open control loop allows a user to set a drying time for drying the clothing articles. Setting the drying time requires an estimation by the user of when the clothing articles will be dry and generally results in the articles being either over-heated or under-heated. Over-heating of clothing articles results in unnecessary longer drying times, higher energy consumption, and the potential for damaging the articles. On the other hand, under-heating causes great inconvenience because the user has to reset the drying time and wait again for the clothing articles to be dry. Accordingly, there is a need for a clothes dryer that can automatically sense the dryness of the clothing articles in a dryer without having to rely on a user's subjective estimation of the drying time.

SUMMARY OF THE INVENTION

In accordance with a first embodiment of this invention, there is provided an appliance such as a clothes dryer for drying clothing articles. In this embodiment, the dryer comprises a container for receiving the clothing articles. A motor rotates the container about an axis. A heater supplies heated air to the container. A duct directs the heated air outside the container. A temperature sensor senses the temperature of the heated air and provides signal representations thereof. A phase angle sensor senses the motor phase angle and provides signal representations thereof. A controller responsive to both the temperature sensor and the phase angle sensor determines the dryness of the clothing articles in the container as a function of the heated air temperature and the motor phase angle.

In accordance with a second embodiment of this invention, there is provided an appliance such as a clothes dryer for drying clothing articles. In this embodiment, the dryer comprises a container for receiving the clothing articles. A heater supplies heated air to the container. A duct directs the heated air outside the container. A humidity sensor senses the humidity of the heated air in the duct and provides signal representations thereof. A controller responsive to the humidity sensor determines the dryness of the clothing articles in the container as a function of the humidity of the heated air. The clothing articles are dry when the humidity signal representations are within a predetermined humidity range and when difference values of the humidity signal representations are within a predetermined interval.

In accordance with a third embodiment of this invention, there is provided an appliance such as a clothes dryer for drying clothing articles. In this embodiment, the dryer comprises a container for receiving the clothing articles. A motor rotates the container about an axis. A heater supplies heated air to the container. A duct directs the heated air outside the container. A temperature sensor senses the temperature of the heated air and provides signal representations thereof. A phase angle sensor senses motor phase angle and provides signal representations thereof. A humidity sensor senses the humidity of the heated air in the duct and provides signal representations thereof. A controller responsive to the temperature sensor, the phase angle sensor, and the humidity sensor determines the dryness of the clothing articles in the container as a function of the heated air temperature, the motor phase angle, and the humidity of the heated air.

DESCRIPTION OF THE DRAWINGS

FIG. **1** shows a perspective view of a clothes dryer used in a first embodiment of this invention;

FIG. **2** shows a block diagram of a controller used in the first embodiment of this invention;

FIGS. **3***a*–**3***c* show a flow chart setting forth the steps used to determine the dryness of the clothing articles used in the first embodiment of this invention;

FIGS. **4***a*–**4***c* are time series plots illustrating the operation of the clothes dryer set forth in the first embodiment of this invention;

FIG. **5** shows a perspective view of a clothes dryer according to a second embodiment of this invention;

FIG. **6** shows a block diagram of a controller used in the second embodiment of this invention;

FIG. **7** shows a flow chart setting forth the steps used to determine the dryness of the clothing articles according to the second embodiment of this invention;

FIGS. **8***a*–**8***c* are time series plots illustrating the operation of the clothes dryer set forth in the second embodiment of this invention;

FIG. **9** shows a perspective view of a clothes dryer according to a third embodiment of this invention; and

FIG. **10** shows a block diagram of a controller used in the third embodiment of this invention.

DETAILED DESCRIPTION OF THE INVENTION

FIG. **1** shows a perspective view of a clothes dryer **10** used in a first embodiment of this invention. The clothes dryer includes a cabinet or a main housing **12** having a front panel **14**, a rear panel **16**, a pair of side panels **18** and **20** spaced apart from each other by the front and rear panels, a bottom panel **22**, and a top cover **24**. Within the housing **12** is a drum or container **26** mounted for rotation around a substantially horizontal axis. A motor **44** rotates the drum **26** about the horizontal axis through a pulley **43** and a belt **45**. The drum **26** is generally cylindrical in shape, having an imperforate outer cylindrical wall **28** and a front flange or wall **30** defining an opening **32** to the drum. Clothing articles and other fabrics are loaded into the drum **26** through the opening **32**. A plurality of tumbling ribs(not shown) are provided within the drum **26** to lift the articles and then allow them to tumble back to the bottom of the drum as the drum rotates. The drum **26** includes a rear wall **34** rotatably supported within the main housing **12** by a suitable fixed bearing. The rear wall **34** includes a plurality of holes **36** that receive hot air that has been heated by a heater such as a combustion chamber **38** and a rear duct **40**. The combustion chamber **38** receives ambient air via an inlet **42**. Although the clothes dryer **10** shown in FIG. **1** is a gas driver, it could just as well be an electric dryer without the combustion chamber **38** and the rear duct **40**. The heated air is drawn from the drum **26** by a blower fan **48** which is also driven by the motor **44**. The air passes through a screen filter **46** which traps any lint particles. As the air passes through the screen filter **46**, it enters a trap duct seal (permagum) and is passed out of the clothes dryer through an exhaust duct **50**. After the clothing articles have been dried, they are removed from the drum **26** via the opening **32**.

In this embodiment the dryness of the clothing articles in the clothes dryer **10** is sensed by using a temperature sensor **52** and a phase angle sensor **54**. The temperature sensor **52** senses the temperature of the heated air passing through the screen filter **46** and the phase angle sensor **54** senses the phase angle of the motor **44** as the drum **26** is rotated. The temperature sensor may be a commercially available sensor such as an Omega thermocouple type K and the phase angle sensor **54** may be a general purpose single phase induction motor sensor. The temperature sensor **52** and the phase angle sensor **54** provide signal representations of the temperature of the heated air and the phase angle of the motor, respectively, to a controller **56**. The controller **56** is responsive to both the temperature sensor **52** and the phase angle sensor **54** and determines the dryness of the clothing articles in the drum as a function of the heated air temperature and the motor phase angle.

The controller **56** determines dryness by deciding when the percentage of water content in the clothing articles reaches a predefined level of water content. The percentage of water content is defined as:

$$\%\ \text{Water Content} = \frac{\text{Weight of Water}}{\text{Weight of Water} + \text{Weight of Articles}} \times 100 \quad (1)$$

In this invention, the percentage of water content is divided into five categories which are classified as wet, less dry, normal, dry, and bone dry. The ranges of percentage of water content for the classifications are 100% to about 16% for the wet classification, about 16% to about 10% for the less dry classification, about 10% to about 5% for the normal classification, about 5% to about 3% for the dry classification, and about 3% to 0% for the bone dry classification. In this embodiment, the controller **56** determines dryness by deciding when the percentage of water content in the clothing articles is in the range of about 10% to about 3% water content, with the preferred range being from about 5% to about 3%. The steps performed by the controller **56** to determine dryness are described below in more detail. Once the controller **56** has determined that the clothing articles are dry, then the controller terminates the drying cycle. An advantage of the present invention over the open control loop dryer is that energy consumption is reduced and there is less potential for damage to the articles due to overheating, since the dryness is automatically detected.

A more detailed view of the controller **56** according to the first embodiment of this invention is shown in FIG. **2**. The controller comprises an analog to digital (A/D) converter **58** for receiving the signal representations sent from the temperature sensor **52** and a counter/timer **60** for receiving the signal representations sent from the phase angle sensor. The signal representations from the A/D converter **58** and the counter/timer **60** are sent to a central processing unit (CPU) **62** for further signal processing. It is also within the scope of this invention to use the clock within the CPU **62** for directly receiving the signal representations from the phase angle sensor **54** instead of the counter/timer **60**. The CPU which receives power from a power supply **64** comprises decision logic stored in a read only memory (ROM) **64** for determining the dryness of the clothing articles in the container as a function of the processed signal representations of the heated air temperature and the motor phase angle. The decision logic used to determine dryness is described below in more detail. Once it has been determined that the clothing articles are dry, then the CPU **62** sends a signal to an output circuit **68** which sends a signal to shut off a cycle selector knob **70** located on a control panel **71** of the dryer **10**. The position of the selector knob **70** is monitored by a position encoder **72** which sends signals to a counter/timer **74** which is connected to the CPU **62**. As the drying cycle is shut off the controller activates a beeper via an enable/disable and beeper circuit **76** to indicate the end of the cycle.

In this embodiment, dryness is based on a correlation between the signal representations of the motor phase angle and the temperature of the heated air. A problem associated with other dryers that only use a motor phase angle to sense dryness is that the conclusions regarding the dryness can be misleading. In particular, as a drying cycle proceeds the clothing articles lose weight continuously because there is less water in the articles. As the clothing articles lose weight the motor phase peak to peak values increase. When these values stop increasing then one can deduce that the clothing articles are already dry, albeit over. Furthermore, the phase angle sensor values are usually noisy and may result in misleading dryness conclusions. This invention has overcome the problems associated with using a motor phase angle sensor by correlating the phase angle signal representations with the signal representations generated from the temperature sensor.

FIGS. **3***a*–**3***c* disclose flow charts setting forth the steps used to determine the dryness of the clothing articles according to the first embodiment of this invention. FIGS. **3***a*–**3***b* disclose the signal processing steps performed on the signal representations generated from the phase angle sensor and the temperature sensor, respectively. The signal processing steps disclosed in both FIGS. **3***a*–**3***b* are performed in parallel in real time. In this invention, the motor phase angle signal representations are logged to the CPU **62** at a sampling rate of 10 Hz, while the temperature signal representations are logged to the CPU at a sampling rate of 1 Hz. In this embodiment, the CPU **62** has five buffers A, B, C, D, and E reserved therein. Buffers A, B, and C are reserved for the phase angle signal representations, while buffers D and E are reserved for the temperature signal representations. Buffer A is capable of storing 14 data points, while Buffers B and C are capable of storing 32 and 4 data points, respectively. For the temperature signal processing, Buffer D is capable of storing 16 data points, while Buffer E is capable of storing 4 data points.

Referring now to FIG. **3***a* the signal processing steps of the phase angle signal representations will be described. The signal processing begins at **78** where the phase angle sensor is read. The phase angle signal is denoted as $P_0(i)$ where i denotes its time sampling sequence. The phase angle signal $P_0(i)$ is transformed into a relative phase angle $P_n(i)$ at **80** wherein $P_n(i)$ equals $90°-P_0(i)$. The $P_n(i)$ data value is placed in Buffer A at **82**. One by one the $P_n(i)$ data values are placed into Buffer A until it has been determined that the buffer is full at **84**. When Buffer A is full, the range of all values stored in the buffer is calculated at **86** and placed into Buffer B at **88** and then Buffer A is flushed at **90**. If Buffer B is not full at **92**, then the phase angle sensor is read again and steps **80**–**90** are repeated until Buffer B is full. When Buffer B is full, the median of all values stored in Buffer B is calculated at **94** and placed into Buffer C at **96** and then Buffer B is flushed at **98**. If Buffer C is not full at **100**, then the phase angle sensor is read again and steps **80**–**98** are repeated until Buffer C is full. When Buffer C is full, the median of all values stored in Buffer C is calculated at **102**. Once the median of all values stored in Buffer C has been calculated then the median value $P_n(i)$ is passed at **104** to the dryness algorithm described below in FIG. **3***c* and Buffer C is flushed at **106**. This process is repeated until the end of the drying cycle.

As mentioned above the signal processing steps for the phase angle and temperature signal representations are performed in parallel in real time. Referring now to FIG. **3***b* the signal processing steps of the temperature signal representations will be described. The signal processing of the temperature begins at **108** where the temperature sensor is read. The temperature signal is denoted as T(j) where j denotes its time sampling sequence. The T(j) data value is placed in Buffer D at **110**. One by one the T(j) data values are placed into Buffer D until it has been determined that the buffer is full at **112**. When Buffer D is full, the median of all values stored in the buffer is calculated at **114** and placed into Buffer E at **116** and then Buffer D is flushed at **118**. If Buffer E is not full at **120**, then the temperature sensor is read again and steps **110–118** are repeated until Buffer E is full. When Buffer E is full, the median of all values stored in Buffer E is calculated at **122**. Once the median of all values stored in Buffer E has been calculated then the median value T(j) is passed at **124** to the dryness algorithm described in FIG. **3***c* and Buffer E is flushed at **126**. This process is repeated until the end of the drying cycle.

Once the signal processing steps for the phase angle and temperature signal representations have been performed the dryness algorithm set forth in FIG. **3***c* is then initiated. Referring now to FIG. **3***c* the dryness algorithm will be described. The dryness detection begins at **128** where T(j) is monitored to determine if its value exceeds 120° F. (49° C.). If the T(j) value does not exceed 120° F. (49° C.), then FIG. **3***b* is initiated at **130** and the temperature sensor is read and steps **110–126** are repeated until T(j) exceeds 120° F. Once T(j) has exceeded 120° F. (49° C.) then T(j) is examined at **132** to find the local maximum. In the present invention, the local maximum is found if $T(j) \geqq T(j-1)$ and $T(j-1) \geqq T(j-2)$. If the local maximum of T(j) has not been found at **134**, then FIG. **3***b* is initiated again at **130** and the temperature sensor is read and steps **110–126** are repeated until the local maximum is found. Once the local maximum has been found then the dryness algorithm switches attention to the phase angle $P_n(i)$ at **136**. The phase angle $P_n(i)$ value is then examined at **138** to find the local minimum. In the present invention, the local minimum is found if $P(i) \geqq P(i-1)$ and $P(i-1) \leqq P(i-2)$. If the local minimum of $P_n(i)$ has not been found at **140**, then FIG. **3***a* is initiated again at **142** and the phase angle sensor is read and steps **80–106** are repeated until the local minimum is found. Once the local minimum has been found then the clothing articles are considered dry and the dryer is shut off at **144**. In essence, dryness is sensed by determining when the signal representations of the heated air temperature have reached a local maximum and the signal representations of the motor phase angle have reached a local minimum.

FIGS. **4***a*–**4***c* are time series plots illustrating the operation of the clothes dryer set forth in the first embodiment according to this invention. FIG. **4***a* is a plot of the phase angle P(i) versus i, the time sampling sequence. More specifically, FIG. **4***a* shows the median of peak to peak phase change over sampling time steps for a particular drying cycle. FIG. **4***b* is a plot of the temperature T(j) versus j, the sampling time steps. FIG. **4***c* is a plot of the percentage of water content versus the sampling time step. In the example illustrated in FIGS. **4***a*–**4***c*, the above described dryness detection algorithm does not begin until the clothes temperature T(j) exceeds 120° F. (49° C.). The first local maximum that is found occurs at time step **17** of FIG. **4***b*. At this time the dryness detection algorithm then searches for the first local minimum of P(i) in FIG. **4***a*. In this example, the first local minimum of P(i) occurs at time step **7** of FIG. **4***a*. Then the dryness detection algorithm will issue a shut-off command at the next time step (i.e. time step **8**) in FIG. **4***a*. At this time the water content in the clothing articles is almost at its lowest value as shown in FIG. **4***c*. Note that the percentage of water content in the clothing articles is well within the range of about 10% to about 3% water content and within the preferred range from about 5% to about 3%. As mentioned above this invention prevents the clothing articles from being over-heated or under-heated and reduces energy consumption.

FIG. **5** shows a perspective view of a clothes dryer **146** according to a second embodiment of this invention. The clothes dryer **146** is similar to the clothes dryer of the first embodiment except that there is neither a temperature sensor nor a motor phase angle sensor in this embodiment. Instead this embodiment uses a humidity sensor **148** for detecting the dryness of the clothing articles. The humidity sensor **148** senses the humidity of the heated air passing through the exhaust duct **50**. The humidity sensor may be a commercial off-the shelf item such as a Parametrics HT-119. The humidity sensor **148** provides signal representations of the humidity of the heated air to a controller **150**. The controller **150** is responsive to the humidity sensor **148** and determines the dryness of the clothing articles in the drum as a function of the humidity of the heated air in the exhaust duct **50**.

A more detailed view of the controller **150** according to the second embodiment of this invention is shown in FIG. **6**. The controller in this embodiment is similar to the controller set forth in the first embodiment except that the counter/timer for receiving the signal representations sent from the phase angle sensor has been removed. In this embodiment an A/D converter receives the signal representations sent from the humidity sensor **148**. The CPU comprises decision logic stored in a ROM for determining the dryness of the clothing articles in the container as a function of the processed signal representations of the humidity of the heated air. A problem associated with other dryers that use humidity to sense dryness is that the typical humidity sensors that are used are quite expensive. The present invention can overcome the cost problems by using a low-end humidity sensor that has a relative humidity range from about 0% to about 30% with a dryness detection algorithm which is described below in more detail.

FIG. **7** discloses a flow chart setting forth the steps used to determine the dryness of the clothing articles according to the second embodiment of this invention. In this embodiment, the humidity signal representations are logged to the CPU at a sampling rate of 1 Hz and the CPU has two buffers A and B reserved therein. Buffer A is capable of storing 16 data points, while Buffers B is capable of storing 4 data points. The signal processing begins at **152** where the humidity sensor is read. The humidity signal is denoted as m(i) where i denotes its time sampling sequence. The m(i) data value is placed in Buffer A at **154**. One by one the m(i) data values are placed into Buffer A until it has been determined that the buffer is full at **156**. When Buffer A is full, the median of all values stored in the buffer is calculated at **158** and placed into Buffer B at **160** and then Buffer A is flushed at **162**. If Buffer B is not full at **164**, then the humidity sensor is read again and steps **154–162** are repeated until Buffer B is full. When Buffer B is full, the median of all values stored in Buffer B is calculated at **166**.

Once the median of all values has been calculated then the median value m(i) is passed to step **168** where the beginning of the dryness detection is initiated.

The m(i) data value is now monitored to determine if its value is less than 30%. If the m(i) value exceeds 30%, then Buffer B is flushed at **170** and the humidity sensor is read again and steps **154–166** are repeated until m(i) is less than 30%. Once m(i) is less than 30% then m(i) is examined at **172** to determine if there are more than two m(i) data values. If there are not more than two m(i) data values then the humidity sensor is read again and steps **154–168** are repeated until there are more than two m(i) data values. Once there are more than two m(i) data values then the difference or derivative in humidity dm(i) is determined at **174**. In this invention, the difference in humidity dm(i) equals m(i)-m(i−1). At step **176**, the dryness algorithm determines whether the difference in humidity dm(i) is the same value for a predetermined interval. In this embodiment, the preferred predetermined interval is three consecutive values that are within a tolerable small band or range. This relationship is described below in equation 2:

$$dm(i-2)\epsilon[-3,3] \text{ and } dm(i-1)\epsilon[-3,3] \text{ and } dm(i)\epsilon[-3,3] \qquad (2)$$

Once it has been determined that there are three consecutive values within the tolerable small band [−3,3] as defined in equation 2, then the clothing articles are considered dry and the dryer is shut off at **178**.

FIGS. **8*a*–8*c*** are time series plots illustrating the operation of the clothes dryer set forth in the second embodiment according to this invention. FIG. **8*a*** is a plot of the humidity m(i) versus i, the time sampling sequence. Note that the scale of the y-axis in FIG. **8*a*** ranges from 0% to 30%. FIG. **8*b*** is a plot of the difference of the humidity signal dm(i) versus i, the sampling time steps. Note that the scale of the y-axis in FIG. **8*b*** ranges in the band from −3 to 3. FIG. **8*c*** is a plot of the percentage of water content versus the sampling time step. In the example illustrated in FIGS. **8*a*–8*c***, the above described dryness detection algorithm detects that there are three consecutive difference in humidity dm(i) values starting after the 30th time step. The dryness detection algorithm then issues a shut-off command at time step **33** where the third consecutive value has been noted. At this time the water content in the clothing articles is stabilized and is almost at its lowest value as shown in FIG. **8*c***. Note that the percentage of water content in the clothing articles is well within the range of about 10% to about 3% water content and within the preferred range from about 5% to about 3%. As mentioned above this invention prevents the clothing articles from being over-heated or under-heated and reduces energy consumption.

FIG. **9** shows a perspective view of a clothes dryer **180** according to a third embodiment of this invention. The clothes dryer **180** is similar to the clothes dryer shown in the first and second embodiment except that in this embodiment there is a temperature sensor **52**, a motor phase angle sensor **54**, and a humidity sensor **148** that are all used for detecting the dryness of the clothing articles. The temperature sensor **52**, the motor phase angle sensor **54**, and the humidity sensor **148** provide signal representations of the temperature of the heated air, the phase angle of the motor, and the humidity of the heated air to a controller **182**, respectively. The controller **182** is responsive to the temperature sensor **52**, the phase angle sensor **54**, and the humidity sensor **148** and determines the dryness of the clothing articles in the drum as a function of the temperature of the heated air, the motor phase angle, and the humidity of the heated air.

A more detailed view of the controller **182** according to the third embodiment of this invention is shown in FIG. **10**. The controller in this embodiment is similar to the controllers set forth in the first and second embodiment except that there is a counter/timer **60** for receiving the signal representations sent from the phase angle sensor **54**, an A/D converter **58** for receiving the signal representations sent from the temperature sensor **52**, and an A/D converter **184** for receiving the signal representations sent from the humidity sensor **148**. The CPU comprises decision logic stored in ROM for determining the dryness of the clothing articles in the container as a function of the processed signal representations of the motor phase angle, the temperature of the heated air, and the humidity of the heated air. The decision logic contains the aforementioned dryness algorithms set forth in FIGS. **3*a*–3*c*** and FIG. **7**. Accordingly, the controller determines the dryness of the clothing articles following the steps set forth in the two aforementioned algorithms. More specifically, if and only if the two algorithms are in agreement, then the clothes dryer shuts off. Like the first and second embodiment, the third embodiment provides another method for detecting the dryness of the clothing articles and that prevents the articles from being over-heated or under-heated and reduces energy consumption. It is therefore apparent that there has been provided in accordance with the present invention, a system and method for sensing the dryness of articles in an appliance that fully satisfy the aims and advantages and objectives hereinbefore set forth. The invention has been described with reference to several embodiments, however, it will be appreciated that variations and modifications can be effected by a person of ordinary skill in the art without departing from the scope of the invention.

What is claimed is:

1. An appliance for drying clothing articles, comprising:

a container for receiving the clothing articles;

a motor for rotating the container about an axis;

a heater for supplying heated air to the container;

a duct for directing the heated air outside the container;

a temperature sensor for sensing the heated air and providing signal representations thereof;

a phase angle sensor for sensing motor phase angle and providing signal representations thereof; and

a controller responsive to both the temperature sensor and the phase angle sensor for determining the dryness of the clothing articles in the container as a function of the heated air temperature and the motor phase angle, the controller comprising a signal processing unit for processing the signal representations of the heated air temperature and the motor phase angle and a decision logic unit for determining the dryness of the clothing articles in the container as a function of the processed signal representations of the heated air temperature and the motor phase angle, wherein the decision logic unit decides whether the processed signal representations of the heated air temperature have reached a local maximum and the processed signal representations of the motor phase angle have reached a local minimum.

2. The appliance according to claim **1**, wherein the controller further comprises a disable unit for terminating the drying cycle of the appliance when the local maximum and local minimum have been reached.

3. The appliance according to claim **1**, wherein the controller comprises a disable unit for terminating the drying cycle of the appliance.

4. The appliance according to claim **1**, wherein the controller uses the signal representations of the heated air temperature and the motor phase angle to determine whether a percentage of water content in the clothing articles has reached a predefined level.

5. The appliance according to claim **4**, wherein the controller comprises a disable unit for terminating the drying cycle of the appliance as the percentage of water content in the clothing articles reaches the predefined level.

6. The appliance according to claim **4**, wherein the predefined level of percentage of water content ranges from about 10% water content to about 3% water content.

7. A clothes dryer, comprising:

a container for accommodating a plurality of clothing articles;

a motor for rotating the container about an axis;

a heater for supplying heated air to the container;

a duct for directing the heated air outside the container;

a temperature sensor for sensing the heated air and providing signal representations thereof;

a phase angle sensor for sensing motor phase angle and providing signal representations thereof; and

a controller responsive to both the temperature sensor and the phase angle sensor for determining the dryness of the plurality of clothing articles in the container as a function of the heated air temperature and the motor phase angle, the controller comprising a signal processing unit for processing the signal representations of the heated air temperature and the motor phase angle and a decision logic unit for determining the dryness of the clothing articles in the container as a function of the processed signal representations of the heated air temperature and the motor phase angle, wherein the decision logic unit decides whether the processed signal representations of the heated air temperature have reached a local maximum and the processed signal representations of the motor phase angle have reached a local minimum.

8. The clothes dryer according to claim **7**, wherein the controller further comprises a disable unit for terminating the drying cycle of the appliance when the local maximum and local minimum have been reached.

9. The clothes dryer according to claim **7**, wherein the controller comprises a disable unit for terminating the drying cycle of the clothes dryer.

10. The clothes dryer according to claim **7**, wherein the controller uses the signal representations of the heated air temperature and the motor phase angle to determine whether a percentage of water content in the plurality of clothing articles has reached a predefined level.

11. The clothes dryer according to claim **10**, wherein the controller comprises a disable unit for terminating the drying cycle of the appliance as the percentage of water content in the clothing articles reaches the predefined level.

12. The clothes dryer according to claim **10**, wherein the predefined level of percentage of water content ranges from about 10% water content to about 3% water content.

13. A method for drying clothing articles, comprising the steps of:

providing a container for receiving the clothing articles;

rotating the container about an axis with a motor;

supplying heated air to the container;

directing the heated air outside the container;

sensing temperature of the heated air and providing signal representations thereof;

sensing motor phase angle and providing signal representations thereof; and

determining the dryness of the clothing articles in the container as a function of the heated air temperature and the motor phase angle, wherein the determining dryness comprises deciding whether the signal representations of the heated air temperature have reached a local maximum and the signal representations of the motor phase angle have reached a local minimum.

14. The method according to claim **13**, further comprising the step of terminating the drying cycle when the local maximum and local minimum have been reached.

15. The method according to claim **13**, wherein the step of determining dryness comprises determining whether a percentage of water content in the clothing articles has reached a predefined level.

16. The method according to claim **15**, further comprising the step of terminating the drying cycle as the percentage of water content in the clothing articles reaches the predefined level.

17. The method according to claim **15**, wherein the predefined level of percentage of water content ranges from about 10% water content to about 3% water content.

18. An appliance for drying clothing articles, comprising:

a container for receiving the clothing articles;

a heater for supplying heated air to the container;

a duct for directing the heated air outside the container;

a humidity sensor for sensing the humidity of the heated air entering the duct and providing signal representations thereof; and

a controller responsive to the humidity sensor for determining the dryness of the clothing articles in the container as a function of the humidity of the heated air, the clothing articles being dry when the humidity signal representations are within a predetermined humidity range and when consecutive difference values of the humidity signal representations are within a predetermined interval.

19. The appliance according to claim **18**, wherein the controller comprises a signal processing unit for processing the signal representations of the humidity of the heated air.

20. The appliance according to claim **19**, wherein the controller further comprises a decision logic unit for determining the dryness of the clothing articles in the container as a function of the processed signal representations of the humidity of the heated air.

21. The appliance according to claim **18**, wherein the controller comprises a disable unit for terminating the drying cycle of the appliance.

22. The appliance according to claim **18**, wherein the predetermined humidity range is from about 0% humidity to about 30% humidity.

23. The appliance according to claim **18**, wherein the predetermined interval is three consecutive difference in humidity values that are within a tolerable band.

24. A clothes dryer, comprising:

a container for accommodating a plurality of clothing articles;

a heater for supplying heated air to the container;

a duct for directing the heated air outside the container;

a humidity sensor for sensing the humidity of the heated air entering the duct and providing signal representations thereof; and

a controller responsive to the humidity sensor for determining the dryness of the plurality of clothing articles in the container as a function of the humidity of the heated air, the plurality of clothing articles being dry when the humidity signal representations are within a predetermined humidity range and when difference values of the humidity signal representations are within a predetermined interval.

25. The clothes dryer according to claim **24**, wherein the controller comprises a signal processing unit for processing the signal representations of the humidity of the heated air.

26. The clothes dryer according to claim **25**, wherein the controller further comprises a decision logic unit for determining the dryness of the plurality of clothing articles in the container as a function of the processed signal representations of the humidity of the heated air.

27. The clothes dryer according to claim **24**, wherein the controller comprises a disable unit for terminating the drying cycle of the dryer.

28. The clothes dryer according to claim **24**, wherein the predetermined humidity range is from about 0% humidity to about 30% humidity.

29. The clothes dryer according to claim **24**, wherein the predetermined interval is three consecutive difference in humidity values that are within a tolerable band.

30. A method for drying clothing articles, comprising the steps of:

providing a container for receiving the clothing articles;

supplying heated air to the container;

directing the heated air outside the container with a duct;

sensing the humidity of the heated air entering the duct and providing signal representations thereof; and

determining the dryness of the clothing articles in the container as a function of the humidity of the heated air, the clothing articles being dry when the humidity signal representations are within a predetermined humidity range and when difference values of the humidity signal representations are within a predetermined interval.

31. The method according to claim **30**, further comprising the step of terminating the drying cycle.

32. The method according to claim **30**, wherein the predetermined humidity range is from about 0% humidity to about 30% humidity.

33. The method according to claim **30**, wherein the predetermined interval is three consecutive difference in humidity values that are within a tolerable band.

34. An appliance for drying clothing articles, comprising:

a container for receiving the clothing articles;

a motor for rotating the container about an axis;

a heater for supplying heated air to the container;

a duct for directing the heated air outside the container;

a temperature sensor for sensing the heated air and providing signal representations thereof;

a phase angle sensor for sensing motor phase angle and providing signal representations thereof;

a humidity sensor for sensing the humidity of the heated air entering the duct and providing signal representations thereof; and

a controller responsive to the temperature sensor, the phase angle sensor, and the humidity sensor for determining the dryness of the clothing articles in the container as a function of the heated air temperature, the motor phase angle, and the humidity of the heated air, the controller comprising a signal processing unit for processing the signal representations of the heated air temperature, the motor phase angle and the humidity of the heated air and a decision logic unit for determining the dryness of the clothing articles in the container as a function of the processed signal representations of the heated air temperature and the motor phase angle, wherein the decision logic unit decides whether the processed signal representations of the heated air temperature have reached a local maximum and the processed signal representations of the motor phase angle have reached a local minimum.

35. The appliance according to claim **34**, wherein the controller further comprises a disable unit for terminating the drying cycle of the appliance when the local maximum and local minimum have been reached.

36. The appliance according to claim **34**, wherein the controller comprises a disable unit for terminating the drying cycle of the appliance.

37. The appliance according to claim **34**, wherein the controller uses the signal representations of the heated air temperature and the motor phase angle to determine whether a percentage of water content in the clothing articles has reached a predefined level.

38. The appliance according to claim **37**, wherein the controller comprises a disable unit for terminating the drying cycle of the appliance as the percentage of water content in the clothing articles reaches the predefined level.

39. The appliance according to claim **37**, wherein the predefined level of percentage of water content ranges from about 10% water content to about 3% water content.

40. The appliance according to claim **34**, wherein the decision logic decides whether the humidity signal representations are within a predetermined humidity range and whether the difference values of the humidity signal representations are within a predetermined interval.

41. The appliance according to claim **40**, wherein the predetermined humidity range is from about 0% humidity to about 30% humidity.

42. The appliance according to claim **40**, wherein the predetermined interval is three consecutive difference in humidity values that are within a tolerable band.

43. A clothes dryer, comprising:

a container for accommodating a plurality of clothing articles;

a motor for rotating the container about an axis;

a heater for supplying heated air to the container;

a duct for directing the heated air outside the container;

a temperature sensor for sensing the heated air and providing signal representations thereof;

a phase angle sensor for sensing motor phase angle and providing signal representations thereof;

a humidity sensor for sensing the humidity of the heated air entering the duct and providing signal representations thereof; and

a controller responsive to the temperature sensor, the phase angle sensor, and the humidity sensor for determining the dryness of the plurality of clothing articles in the container as a function of the heated air temperature, the motor phase angle, and the humidity of the heated air, the controller comprising a signal processing unit for processing the signal representations of the heated air temperature, the motor phase angle and the humidity of the heated air and a decision logic unit for determining the dryness of the clothing articles in the container as a function of the processed signal representations of the heated air temperature and the motor phase angle, wherein the decision logic unit decides whether the processed signal representations of the heated air temperature have reached a local maximum and the processed signal representations of the motor phase angle have reached a local minimum.

44. The clothes dryer according to claim **43**, wherein the controller further comprises a disable unit for terminating the drying cycle of the clothes dryer when the local maximum and local minimum have been reached.

45. The clothes dryer according to claim **43**, wherein the controller comprises a disable unit for terminating the drying cycle of the clothes dryer.

46. The clothes dryer according to claim **43**, wherein the controller uses the signal representations of the heated air temperature and the motor phase angle to determine whether a percentage of water content in the plurality of clothing articles has reached a predefined level.

47. The clothes dryer according to claim **46**, wherein the controller comprises a disable unit for terminating the drying cycle of the clothes dryer as the percentage of water content in the plurality of clothing articles reaches the predefined level.

48. The clothes dryer according to claim **46**, wherein the predefined level of percentage of water content ranges from about 10% water content to about 3% water content.

49. The clothes dryer according to claim **43**, wherein the decision logic decides whether the humidity signal representations are within a predetermined humidity range and whether the difference values of the humidity signal representations are within a predetermined interval.

50. The clothes dryer according to claim **49**, wherein the predetermined humidity range is from about 0% humidity to about 30% humidity.

51. The clothes dryer according to claim **49**, wherein the predetermined interval is three consecutive difference in humidity values that are within a tolerable band.

52. A method for drying clothing articles, comprising the steps of:

providing a container for receiving the clothing articles;

rotating the container about an axis with a motor;

supplying heated air to the container;

directing the heated air outside the container with a duct;

sensing temperature of the heated air and providing signal representations thereof;

sensing motor phase angle and providing signal representations thereof;

sensing the humidity of the heated air entering the duct and providing signal representations thereof; and

determining the dryness of the clothing articles in the container as a function of the heated air temperature, the motor phase angle, and the humidity of the heated air, wherein the determining dryness comprises deciding whether the signal representations of the heated air temperature have reached a local maximum and the signal representations of the motor phase angle have reached a local minimum.

53. The method according to claim **52**, further comprising the step of terminating the drying cycle when the local maximum and local minimum have been reached.

54. The method according to claim **52**, wherein the step of determining dryness comprises determining whether a percentage of water content in the clothing articles has reached a predefined level.

55. The method according to claim **54**, further comprising the step of terminating the drying cycle as the percentage of water content in the clothing articles reaches the predefined level.

56. The method according to claim **55**, wherein the predefined level of percentage of water content of saturated clothing articles ranges from about 10% water content to about 3% water content.

57. The method according to claim **52**, wherein step of determining the dryness of the clothing articles comprises determining when the humidity signal representations are within a predetermined humidity range and when difference values of the humidity signal representations are within a predetermined interval.

58. The method according to claim **57**, wherein the predetermined humidity range is from about 0% humidity to about 30% humidity.

59. The appliance according to claim **57**, wherein the predetermined interval is three consecutive difference in humidity values that are within a tolerable band.

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